THE EXPERIMENTAL STUDY AND NUMERICAL SIMULATION OF FALLING LIQUID FILM FLOW ON HORIZONTAL TUBES

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I wish to dedicate especially to
my beloved family , supervisor, co-supervisor, colleagues and those who have guided and inspired me throughout my journey of education.

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ABSTRACT

This research is motivated by two observations: No report has been found so far in studies of water falling film up to 100 mm intertube spacing. No simulation analysis of film thickness under influence of intertube spacing in 3 dimensional models. Therefore, to the best of author's knowledge, this research aims to illuminate the effects of intertube spacing between horizontal tubes on water falling film. An experimental investigation of water falling film temperature was conducted to explore the characteristics of heat transfer coefficients. In this study, the intertube spacing from smallest size of 8 mm and up to 100 mm were analyzed for Reynolds number range of 300 to 3300. The experimental data was extracted from calibrated test rig and the effect is investigated using numerical study. On the other hand, the effect of film thickness is numerically investigated for intertube spacing range of 10 mm to 40 mm. The numerical simulation was presented using the Volume of Fluid (VOF) technique where it is capable in determining temperatures and thickness of water falling film under influence of ambient factors. The experimental results reveal that intertube spacing of 133 mm produced the maximum heat transfer coefficient of 6 kW/m^2 K with percentage of error below 7%. The results of the numerical simulation indicate that the 40 mm intertube spacing presented the minimal average film thickness of 0.3 mm within ± 50% errors. Implications of the results and future research directions are also presented.

ABSTRAK

Faktor pendorong terhadap penyelidikan ini adalah berdasarkan kepada dua pemerhatian utama iaitu: Kajian terhadap lapisan air yang mengalir di antara dua tiub mendatar masih belum dijalankan bagi jarak melebihi 100 mm. Kajian simulasi untuk mengukur ketebalan lapisan air secara 3-dimensi juga masih belum pernah dijalankan di bawah pengaruh jarak di antara tiub mendatar tersebut. Oleh itu, sebagai pilihan yang terbaik daripada penulis, penyelidikan ini bermatlamat untuk menjelaskan kesan perubahan jarak di antara tiub mendatar terhadap lapisan air yang mengalir melaluiya. Penyelidikan terhadap suhu pada lapisan air yang mengalir tersebut bertujuan untuk menerokai sifat bagi pekali pemindahan haba yang telah dihasilkannya. Di dalam kajian ini juga, pelbagai jarak di antara tiub mendatar telah dianalisa, iaitu bermula dari saiz terkecil 8 mm hingga melebihi 100 mm dengan nombor Reynolds berada pada julat 300 - 3000. Data ujikaji tersebut telah dihasilkan dari pelantar ujian dengan pelarasan kejituan yang tinggi. Kesan terhadap suhu ini juga diselidiki secara kajian berangka. Selain itu, ketebalan lapisan air pada permukaan tiub juga telah diselidiki secara kajian berangka bagi saiz di antara tiub mendatar 10 mm hingga 40 mm. Simulasi berangka di dalam penyelidikan ini telah dijalankan dengan kaedah VOF dimana ia berkemampuan untuk mengukur suhu dan ketebalan lapisan air di bawah pengaruh faktor-faktor persekitaran yang sebenar. Hasil keputusan ujikaji menunjukkan bahawa jarak di antara tiub mendatar 133 mm telah menghasilkan pekali pemindahan haba yang maksimum iaitu 6 kW/m^2 K dengan peratusan ralat di bawah 7%. Hasil keputusan secara kajian berangka pula menunjukkan bahawa saiz di antara tiub mendatar 40 mm telah menghasilkan ketebalan lapisan air yang minimum iaitu 0.3 mm dengan peratusan ralat ± 50%. Implikasi daripada keputusan serta halatuju kajian pada masa hadapan turut dibentangkan.

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LIST OF SYMBOLS

Symbols		Quantity	Units
1	-	Inlet point	
2	-	Exit point	
a	-	Air or Gas	-
α	-	Magnification Factor	-
A	-	Surface Area of Fluid Passed Through	m^2
Ar	-	Archimedes Number	-
c	-	Coefficient Values	-
C_p	-	Specific Heat of Water	kJ/kg K
d	-	Outside Diameter of Tube	m
δ	-	Average Falling Film Thickness on Tube Surface	m
δ_i	-	Local Film Thickness on Tube Surface	m
D_h	-	Hydraulic Diameter	m
$\vec{F}_\sigma$	-	surface tension vector	N/m
g	-	Gravitational Acceleration	m/s^2
$\vec{g}$	-	gravity vector	m/s^2
H	-	Feeder Height	m
H_{steam}	-	Steam Generation Rate	kg/m s
h	-	Water Elevation Height	m
h_{heat}	-	Heat Transfer Coefficient	$Wm^{-2}K^{-2}$
h_{fg}	-	Latent heat (enthalpy) of evaporation	J/kg
f	-	Number of Frequency in Hertz	Hz
i	-	Real Whole Number	-
k	-	Thermal Conductivity	W/m K
l	-	Length of Tube	m

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